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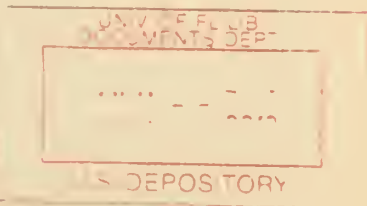
EXPERIMENTS ON THE APPLE WITH SOME
NEW AND LITTLE-KNOWN FUNGICIDES.

BY

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[Cir. 58]

EXPERIMENTS ON THE APPLE WITH SOME NEW AND LITTLE-KNOWN FUNGICIDES.^a

INTRODUCTION.

For many years Bordeaux mixture has been the leading fungicide for summer treatment of the apple, the pear, and certain other fruits. It was soon found, however, that it could not be used on the peach and the Japanese plum, as it caused serious shot-holing of the leaves and summer or premature defoliation of these trees.

Injury caused by Bordeaux mixture has not been confined wholly to the peach. There has been an increasing number of complaints during the last few years about russetting or spray injury to the fruit of the apple due to this mixture. Not only the fruit is injured, but trouble has occurred on the foliage also, in the form of dead spots, minute reddish flecks, yellowing, and, what is still more serious, defoliation.

The fruit russetting has been pretty clearly recognized as due to the spraying with copper. Minute reddish flecks on the fruit and particularly the spotting and flecking of the foliage have been less clearly attributed to copper poison, some pathologists and fruit growers understanding it, while others have mistaken the copper injury for disease. While Bordeaux mixture has been the most useful and successful fungicide that has ever been discovered, it has been open to this serious objection, which for some unknown reason has increased in recent years.

^a This paper is a preliminary report on some experiments on the apple with nine different fungicides carried on in Virginia during the season of 1909. Among these, an iron sulphid and a copper sulphid were sufficiently different from those previously used to be regarded as new. The experiments were conducted in connection with a study of the russet problem or spray injury to apples caused by Bordeaux mixture. If the results can be relied upon they will help materially in solving this problem. While the results with the new mixtures were favorable, the author very properly does not recommend them for general use, but only for trial in an experimental way. The interest in fungicides and in spraying fruit trees is so great and the demand on the part of fruit growers for prompt information is so insistent that it seems desirable to give out these results before they can be further tested.—G. H. POWELL, *Acting Chief of Bureau*.

The matter became so serious that a special investigation was started, and a series of field experiments was undertaken at Winchester, Va., during the season of 1909 for the purpose of solving, if possible, this russetting or spray-injury problem. These experiments consisted in testing, by spraying, nine different fungicides. In the test were included standard Bordeaux mixture, self-boiled lime-sulphur, and various modifications of Bordeaux mixture. These were the most promising fungicides known to the writer. Included in the test were two new fungicides, a new form of copper sulphid and a new iron sulphid, that were tested for the first time. To our surprise these two new mixtures proved remarkably good and among the best. The new iron sulphid, particularly, may have a promising future.

A full report on the experiments just mentioned, with illustrations and with a discussion of the russet problem, is in preparation, but as the interest in spraying and spray materials is so great and the full report may not be ready in time for the spraying season, this preliminary report is given out, particularly for the purpose of describing the two new fungicides and the results obtained with them.

Mr. F. V. Rand, Scientific Assistant, aided in carrying on the spraying work and in taking notes of the results.

PLAN OF THE EXPERIMENT.

SERIES 1.

The main experiment was carried out on the place of Mr. S. L. Lupton, at Winchester, Va. The most complete series, containing eleven plats, known as Series I, was on Mr. Lupton's home farm.

The following shows the formulas of the fungicides used on the various plats:

Plat 1.—Control, unsprayed.

Plat 2.—Standard Bordeaux mixture (3-3-50).

Plat 3.—Iron Bordeaux mixture (3-3-50 plus 2 pounds of copperas, or iron sulphate).

Plat 4.—Standard Bordeaux mixture plus gypsum (3-3-50 plus 3 pounds of gypsum).

Plat 5.—Neutral Bordeaux mixture (3-X-50, X equaling lime added until the neutral point as shown by the litmus test is reached).

Plat 6.—Self-boiled lime-sulphur (10-10-50).

Plat 7.—Copper-sulphid mixture No. 1 (self-boiled lime-sulphur, 10-10-50, plus 2 pounds of copper sulphate).

Plat 8.—Copper-sulphid mixture No. 2 (Bordeaux mixture, 3-3-50, plus 1 gallon of commercial lime-sulphur solution).

Plat 9.—Iron-sulphid mixture (self-boiled lime-sulphur, 10-10-50, plus 3 pounds of copperas or iron sulphate).

Plat 10.—Arsenate of lead (used alone), 2 pounds to 50 gallons.

Plat 11.—Control, unsprayed.

To each of these fungicides arsenate of lead in the form of the ordinary paste was added at the rate of 2 pounds per 50 gallons of spray mixture.

The orchard in which this series of plats was located was planted in strips of four rows each of Ben Davis, Yellow Newtown,^a and York Imperial trees. Each plat consisted of a row running across the varieties so as to include 4 Ben Davis, 4 Yellow Newtown, and 2 York Imperial trees. The Ben Davis was known to be very badly affected by russetting, the Yellow Newtown moderately affected, and the York Imperial notably immune to this type of injury.

SERIES II.

The blossoms being somewhat scant on the block on the home farm and the trees not especially strong and productive, a duplicate series (Series II) was arranged in Mr. Lupton's Baker orchard in a block consisting entirely of Ben Davis trees. This second series was carried out on the same plan, with the exception of plats 8 and 9, which were left out, as they were not considered especially promising when this series was started. The trees in both blocks were 14 years of age. Some trees were missing in the plats of Series I. Each plat in Series II consisted of 4 Ben Davis trees rather heavily fruited, each carrying several barrels of apples.

SUPPLEMENTAL SERIES.

A supplemental series, in which the self-boiled lime-sulphur and the copper-sulphid mixture were used on the Ben Davis variety, was carried out in the orchard of Mr. Stewart Bell. Another supplemental test on the York Imperial and the Ben Davis was carried out in the orchard of Mr. Phil Gold, comparing self-boiled lime-sulphur and standard Bordeaux mixture, the dates of treatment being approximately the same as in Series I and II.

DATES OF APPLICATION OF THE SPRAYS.

The sprays were applied with an ordinary hand barrel pump, a nozzle with a fairly small opening which produced a tolerably fine mist-like spray being used. The first application was made May 11 and 12, shortly after the petals had fallen, while the calyxes were still open. The second application was made June 11 and 12, just a month later; in fact, a week later than was intended. The third application was made July 19.

The first application was made in time to fill the calyx cups with the arsenate and in good season to catch early infections of cedar rust and leaf-blight. This is usually also a timely application to protect from apple scab, though not thoroughly reliable in a bad season. It

^a This variety is known also as Newtown Pippin, and in Virginia as Albemarle Pippin, or simply Pippin.

represents the time of the second treatment for that disease, the first one being made just before the petals open.

The second application, on June 11, while it answered very well under the conditions at Winchester, might be regarded as a little late. June 1 to 5 would be a better time for this application in ordinary years. This application is intended to catch the codling moth at the time of hatching and feeding, and as the trees are just in full leaf it is the best single treatment for apple leaf-blight or leaf-spot, though a little late for the cedar-rust fungus.

The third application was made on July 19. This was also perhaps a week too late, but is an excellent date for the last summer treatment for fruit spots and leaf diseases and is timely for the second brood of codling moths and for the lesser apple worm. The spray applied at this time is expected to cling to the fruit and foliage and protect them from fungous attacks for the rest of the season. Only under unfavorable conditions and on varieties subject to attack by the bitter-rot fungus are later treatments necessary. In unfavorable seasons one or, perhaps, two additional treatments might be necessary for the bitter-rot.

The dates specified were arranged in conference with Prof. A. L. Quaintance, of the Bureau of Entomology, who is responsible for such matters as relate to insects and insecticides in this circular.

PREPARATION OF THE SPRAYS.

Plat 2, standard Bordeaux mixture, 3-3-50 formula.—Heretofore, stronger mixtures of bluestone and lime have been regarded as the standard, but for the purpose of this experiment the 3-3-50 Bordeaux mixture was used as the standard. It was made up in the ordinary way, a stock solution of bluestone and a stock mixture of slaked-lime paste being used. The materials were diluted and run together by gravity into a tank.

To this mixture, as to all the other fungicides, 2 pounds of arsenate of lead mixed up to a cream and passed through a sieve were added as the last step before filling into the spray tank. The result was a rather light sky-blue mixture, which stood up very well without settling.

Plat 3, iron Bordeaux mixture.—On plat 3 was used standard 3-3-50 Bordeaux mixture, as on plat 2, to which 3 pounds of dissolved iron sulphate diluted in about 6 gallons of water were added. Space was left in pouring the bluestone and lime together to allow for the addition of the diluted iron sulphate. The iron produced a brown color.^a

^a The addition of iron sulphate to Bordeaux mixture as a sticker has been recommended by Prof. A. D. Selby, of Ohio.

Plat 4, gypsum Bordeaux mixture.—This was prepared in the same manner as the spray for plat 3, 3-3-50 Bordeaux mixture being made up and 3 pounds of gypsum mixed with 6 or 8 gallons of water added in filling the barrel. No change in color resulted.

Plat 5, neutral Bordeaux mixture.—This spray was made in the same manner as standard Bordeaux mixture, except that a very small quantity of lime was used and an excess of bluestone in running the materials into the barrel. With the excess of bluestone, blue litmus paper is turned red. Lime was cautiously added until no marked change was produced in either the blue or the red litmus paper.

Plat 6, self-boiled lime-sulphur.—In these experiments, the rather strong 10-10-50 self-boiled lime-sulphur was purposely used, so that if spray injury resulted it would occur at its worst. In making up the iron sulphid and the copper sulphid mixtures, therefore, the same formula of 10-10-50 was used. In commercial work, however, the 8-8-50 formula should be used.

Briefly stated, this mixture is made up as follows:

In a barrel holding 50 gallons place 8 pounds of good stone lime. Pour over this enough water to nearly cover it. As the lime begins to slake, dump in the sulphur. This should preferably be run through a screen, to break up lumps, and mixed with water to the consistency of a slush. Stir the sulphur into the slaking lime with a strong paddle and add water enough to keep the lime from burning and to keep the mixture in a slushy condition. The stirring should continue occasionally until the greater portion of the lime is slaked into a cream or paste. Meantime the barrel should be covered with burlap sacks or a piece of old carpet or otherwise protected to retain the heat. At the end of fifteen or twenty minutes the lime will be found to be thoroughly slaked and the sulphur partly combined with it. Considerable brown discoloration shows the extent of the chemical combination. The mixture is then diluted, first with a small quantity of water stirred in with a paddle and then sufficiently to fill the barrel to the 50-gallon mark. Space is left before finishing to add the 2 pounds of arsenate of lead, stirred in, in the form of milk, in 2 or 3 gallons of water.

Plat 7, copper-sulphid mixture, No. 1.—To make this spray the self-boiled lime-sulphur, already described (10-10-50), was used as a basis. Space was left to add 2 pounds of copper sulphate in solution, diluted with about 6 or 8 gallons of water. This turned the mass a decidedly bright reddish brown color as it was stirred into the mixture. On the addition of 2 pounds of arsenate of lead, previously mixed with water into a milk, no additional change in color was apparent. This may have been due to inability to detect

any further color change on account of the dark color of the copper sulphid. This mixture is somewhat parallel in a general way as a summer spray with the Oregon wash (so called) as a winter spray.

The Oregon wash is made by adding bluestone solution to the strong home-boiled lime-sulphur mixture and is used only for a winter wash. It is more nearly like the copper-sulphid mixture tried by W. H. Volck, County Entomologist, Watsonville, Cal., and described in a report on powdery mildew of the apple.^a The copper sulphid used by Volck was made by adding bluestone to the commercial lime-sulphur solution. This resulted in a strong mixture which could not be used at once but, according to Mr. Volck, on decanting and washing, it could be sprayed on the apple trees. The washing, however, required two or three days.

The new feature in making the copper-sulphid mixture is the use of the self-boiled lime-sulphur as a basis. This is so mild in its composition as to permit the immediate use of the mixture without washing.

Plat 8, copper-sulphid mixture, No. 2.—This is a copper-sulphid mixture made by using the standard Bordeaux mixture (3-3-50) as a basis and adding a gallon of the strong commercial lime-sulphur stock solution diluted in 2 or 3 gallons of water after the bluestone and lime have been combined. This is also a mixture somewhat similar to that used by Volck,^a but is different in that it has an excess of lime, a part of which is combined with bluestone before adding the sulphur. On account of wanting to use this mixture at once without washing and being afraid of its caustic action, only 1 gallon of the lime-sulphur solution per 50 gallons was used, though 1½ gallons can be used in water alone.^c The mixture gave the light reddish brown color characteristic of the copper sulphid. It was applied without washing or decanting.

Plat 9, iron-sulphid mixture.—The new form of iron-sulphid mixture is made by using the self-boiled lime-sulphur (10-10-50) as a basis. A barrel of the self-boiled lime-sulphur is prepared as already described and diluted to about 40 gallons. Iron sulphate (copperas), 3 pounds, dissolved in 6 to 8 gallons of water, is then added. The iron sulphate might perhaps be still further diluted to advantage. When this is added and stirred into the barrel the mixture turns inky black. Then 2 pounds of arsenate of lead are added, as before.

The iron sulphate can be weighed out and dissolved in a large bucket by stirring, or, better, it can be prepared in a stock solution,

^a "The Apple Powdery Mildew in the Pajaro Valley," Special Bulletin No. 1, by W. H. Volck, County Entomologist for Monterey and Santa Cruz counties. Watsonville, Cal., May, 1909.

as is customary with copper sulphate, at the rate of 1 pound to the gallon of water.

The new feature in this iron sulphid, as in the new copper sulphid, consists in using the self-boiled lime-sulphur as a basis instead of the concentrated lime-sulphur solution. Volek, in the bulletin already cited, described an iron sulphid like his copper sulphid, made by adding iron sulphate to the lime-sulphur solution. But this, like the copper sulphid, required decanting and washing for two or three days to render it suitable for use upon foliage. It was decided to use the self-boiled lime-sulphur in the hope of getting a more harmless mixture which could be made up and used at once, as the washing was not considered practicable or was, at least, very objectionable. The plan succeeded in that the mixture was quite harmless. The inky black mixture was apparently colloidal or somewhat gelatinous in texture and after drying on the trees turned a dark slate color. In a few days this oxidized to a reddish brown color, which remained constant.

RESULTS.

Apple leaf-spot and the cedar-rust fungus began to appear on the leaves of the unsprayed trees at the date of the second treatment. Furthermore, a rather vicious spray injury of the foliage and russetting of the fruit began to appear on the Bordeaux-mixture plats at the same time. The taking of notes of the results was begun, therefore, at that time and continued at frequent intervals throughout the season. The fruit was sorted and weighed at picking time and a sample box of apples from each important plat was packed and placed in cold storage. Careful notes on the condition of the fruit from the different plats were taken at picking time and again at the time the fruit was removed from cold storage, when it was placed on exhibition before the Virginia State Horticultural Society, January 5 to 7. The details as to the differences between these plats and between the resulting fruits may be described more fully in a later publication. For the present purpose, however, the following important results may be stated:

SERIES I.

All the fungicides protected the trees almost completely from fungous diseases, and since the arsenate of lead was combined with them they also controlled the codling moth and other insect pests. It therefore became a question, as was intended from the start, of determining the merits of the different mixtures largely through their effect in producing spray injury.

Plat 1, control.—The extent of damage to the leaves of this plat by fungous diseases was estimated at 60 per cent on September 21, a week before picking time, and the damage to fruit from fungous fruit spots and insect injuries was estimated at 90 per cent on the Ben Davis (of which slightly more than half was due to the codling moth), 20 per cent on the Yellow Newtown (of which three-fifths was caused by the codling moth), and 10 per cent on the York Imperial (of which three-tenths was codling-moth injury).

Plat 2, standard Bordeaux mixture.—The fungous damage to the leaves in this plat was estimated on September 21 at 1 per cent on the Ben Davis trees, and the fungous and insect damage to the fruit at 2 per cent. This was merely nominal. On the other hand, the injury to the leaves by copper poisoning on the date mentioned was estimated at 30 per cent, and the fruit russetting at 60 per cent. This was the greatest percentage of damage to any of the fruit by any of the sprays. The only damage of greater extent was that to the Yellow Newtown leaves, which were marked 80 per cent injured. The reverse was true of the Yellow Newtown fruit, only 30 per cent of which was injured. About 25 per cent of the York Imperial leaves was injured, while only 3 per cent of the fruit was injured by spray russetting.

Since the fruit of the Ben Davis was very susceptible to spray injury throughout, the relative merits of some of the less desirable sprays can be described by giving the percentage of spray injury alone. In the case of some of the following mixtures, therefore, it will be the only figure given.

Plat 3, iron Bordeaux mixture.—This caused but little more than half the injury of standard Bordeaux mixture. The fruit russetting on the Ben Davis was marked 40 per cent.

Plat 4, gypsum Bordeaux mixture.—This was just about half as injurious to fruit and foliage as standard Bordeaux mixture. Russetting on the Ben Davis was marked 30 per cent.

Plat 5, neutral Bordeaux mixture.—At first this was not quite as injurious as standard Bordeaux mixture, but eventually the fruit russetting on the Ben Davis was so nearly the same as to be indistinguishable, and the injury mark given was 60 per cent. Strange to say, this mixture was the only one which seriously injured the fruit of the York Imperial, its use resulting in 20 per cent of injury on that variety. It was therefore more injurious on the whole than standard Bordeaux mixture.

Plat 6, self-boiled lime-sulphur.—Fruit russetting was practically avoided by the use of this mixture. There was a mark of one-half of 1 per cent of russetting given to the Ben Davis fruit. This was merely nominal, however, and was in the stem end of the apples, prob-

ably due to water or to the lead arsenate. No other russet injury to fruit was noted, but a few fungous spots were found on the leaves.

Plat 7, copper-sulphid mixture No. 1.—This mixture russeted the fruit of the Ben Davis the least of any copper spray. The mark given was 10 per cent, or one-sixth of the damage caused by standard Bordenaux mixture. On the other hand, the leaf injury was only 1 per cent, so slight as to be scarcely noticeable, and on the Yellow Newtown and the York Imperial practically perfect marks were given to this mixture. On both leaves and fruit this mixture could be used commercially under the conditions of the past season on these varieties, and were it not for the slight russetting on the Ben Davis it would have ranked with the best and had practically perfect marks throughout. Possibly, by diluting, this injury could be reduced still further.

Plat 8, copper-sulphid mixture No. 2.—This spray was made with the strong lime-sulphur solution instead of the self-boiled lime-sulphur and was inferior to the copper-sulphid mixture No. 1. The damage to the fruit of the Ben Davis, however, was marked 15 per cent, only slightly greater, but the foliage injury was quite serious, reaching 40 per cent on the Yellow Newtown. Substituting the commercial lime-sulphur solution in making the copper sulphid increased the russetting from 10 to 15 per cent on the fruit of the Ben Davis and resulted in some considerable injury to the foliage, 15 per cent on the York Imperial and 10 per cent on the Ben Davis.

Plat 9, iron-sulphid mixture.—This new fungicide received practically perfect marks both as to fungicidal action and as to injury. In the matter of record, or percentage of spray injury and percentage of fungous spots, it scored the highest mark. It has, however, a slight physiological effect on the apple, which is described later, that may sometimes be disadvantageous. There was absolutely no injury in the way of russetting the fruit even on the Ben Davis.

There is a slight russetting around the stems of apples in humid climates that is caused by water in the form of rain or dew in the cavity. The only apples free from this slight stem russetting are those grown in desert or dry countries. The stem russetting on the iron-sulphid plat, however, was reduced to the smallest quantity, being so slight that it was considered exactly the same as that on unsprayed fruits. There was absolutely no injury, and the iron sulphid prevented the fungous diseases so completely that by close observation only a few spots could be found on the leaves. A mark of one-half of 1 per cent for fungous injury was therefore given to each variety. On the fruit no spots were found and a perfect mark was given.

The fruit on the iron-sulphid plat was slightly greener in appearance than the unsprayed fruit, particularly toward the stem end. This

was not so noticeable on the York Imperial; in fact, it was scarcely apparent on that variety. On the Yellow Newtown spraying with copper sulphid resulted in bright-green and apparently slightly belated fruit of such a nature as probably not to be objectionable in that variety. Although the fruit of the Ben Davis was fine looking, it was not quite so brilliant in appearance as that on the lime-sulphur plat. Possibly it might have improved by hanging on the trees a week longer and getting somewhat riper.

On the other hand, the foliage on the iron-sulphid plat was handsomer than that on any of the other plats. It was darker green and, as was afterwards found, it hung on longer than that in any other part of the orchard. During the summer the spray stuck so tightly and was so abundant as to give the trees a brownish appearance, but this wore off at picking time, resulting in a remarkably fine dark-green appearance of the leaves. The twigs were also more stocky and the fruit buds plumper on these trees, although the self-boiled lime-sulphur was a close rival in this respect. This fine appearance of the twigs and buds was undoubtedly produced by the excellent foliage.

Plat 10, arsenate of lead (used alone).—This spray gave excellent results, not only in its absence of injurious effects on the foliage and fruit but in preventing fungous diseases. The injury was marked zero throughout. No injury could be found that was due to spraying or that was in any way abnormal. The slight stem russetting, as with the iron sulphid, was considered natural water russetting. Furthermore, the spraying seemed to protect the fruits from the fly-speck, the smut fungus, and the fruit spots, just as in the case of the other mixtures. On the leaves, however, a few spots of cedar rust and leaf-spot were found, 1 per cent on the Ben Davis, 1 per cent on the Yellow Newtown, and 3 per cent on the York Imperial.

On the whole, the plat sprayed with arsenate of lead compared very favorably with the better plats. The leaves did not have such a handsome and dark-green appearance as those on the iron-sulphid plat, nor even as those on the self-boiled lime-sulphur plat. The foliage, however, seemed to be perfectly natural, making it appear that the extra-good plats were stimulated by the fungicides.

Plat 11.—No records were taken of plat 11, as unfortunately it received by accident some of the treatment with 2-3-50 Bordeaux mixture and arsenate of lead in spraying the surrounding orchard.

Remainder of the orchard.—The mixture used in the remainder of the orchard was a diluted Bordeaux mixture, 2-3-50 (2 pounds of bluestone, 3 pounds of lime, and 50 gallons of water), to which were added 2 pounds of arsenate of lead. This gave good results on the Yellow Newtown and the York Imperial, particularly on the latter

variety. There was some leaf injury, however, on the York Imperial and the Yellow Newtown, becoming serious on many of the trees. It probably amounted to about one-half or two-thirds of that on the 3-3-50 plat. This difference is attributed to the smaller amount of copper in the mixture and to the excess of lime, and possibly also to the somewhat lighter spraying used in commercial work. The results on the fruit were satisfactory even on these varieties. This was also true as to the leaves of the Ben Davis, the injury not being very serious, but the fruit of this variety was very decidedly injured in this orchard, the injury amounting to at least 30 or possibly 40 per cent. The possibility of getting such an injury on the Ben Davis shuts out the use of Bordeaux mixture on that variety.

SERIES II.

In Series II, which contained only Ben Davis trees, the general results were exactly the same as in Series I. Any differences were so slight as to be attributed to accidental variation. The plats of four trees each of the Ben Davis carried heavy crops of fruit, rendering the difference in quality of the fruit rather more emphatic, perhaps, than in Series I. The foliage on these trees was somewhat stronger, and therefore withstood the spray injury slightly better. Unfortunately, plats 8 and 9 were left out of this series.

In Series II the same numbers were used as in Series I to designate the plats sprayed with different mixtures. All of the plats receiving copper spray were injured more or less. The injury seemed to be slightly less, however, at picking time than a month before, as these strong trees outgrew the russetting slightly. On plat 2, however, where the standard Bordeaux mixture was used, fruit russetting amounted to 35 per cent on September 21. The trees sprayed with the iron Bordeaux and the gypsum Bordeaux mixtures were slightly less russeted than those in Series I. Plat 7, sprayed with copper sulphid, gave a corresponding result, the injury being marked 8 per cent, which was the least caused by any copper spray. The self-boiled lime-sulphur gave the same excellent results. This was also true of the arsenate of lead used alone.

SUPPLEMENTAL SERIES.

In the supplemental series in the orchard of Mr. Stewart Bell, the unsprayed plat gave about the same unfavorable result but was not quite so badly affected by fungous diseases as in Series I. The leaves were marked 50 per cent injured by fungi, however, on September 8. The self-boiled lime-sulphur gave satisfactory results, with no russetting whatever, except a trace at the stem end, preventing the fruit spots and the leaf spots and, with the addition of the arsenate of

lead, the greater part of the insect injuries. Of plat 7, the copper-sulphid mixture gave the same excellent results on the leaves, but produced 15 per cent of russeting on the fruit of the Ben Davis.

In the supplemental test in the orchard of Mr. Phil Gold, self-boiled lime-sulphur was used in comparison with standard Bordeaux mixture, 3-5-50. Plats 2 and 6 were located in an orchard which had been quite seriously attacked by the cedar rust. The two varieties York Imperial and Ben Davis were in alternate rows and were included in each plat. In the plat sprayed with Bordeaux mixture the Ben Davis trees showed 15 per cent of injury to the foliage, and the fruit was considerably russeted. It carried one-half of 1 per cent of cedar rust. The York Imperial trees had about 10 per cent of leaf injury from copper poisoning and had smooth fruit, as usual, but carried $2\frac{1}{2}$ per cent of cedar rust. On the plat sprayed with self-boiled lime-sulphur, corresponding to plat 6 of the main series, there was no spray injury to fruit or leaves of either variety, but there was a marked increase in the cedar rust, about 2 per cent on the Ben Davis and 17 per cent on the York Imperial. Self-boiled lime-sulphur, therefore, did not prove entirely successful in controlling cedar rust.

SUMMARY OF RESULTS.

All types of Bordeaux mixture were injurious. On the Ben Davis, particularly on the fruit, the extent of this injury was so great as to compel the abandonment of Bordeaux mixture for spraying this variety. On the Yellow Newtown, while the fruit suffered very much less, the foliage suffered to a great extent, reaching a damage estimated at 80 per cent, the highest percentage of injury produced by any of the sprays. On the York Imperial the fruit was hurt but very little except with neutral Bordeaux mixture. With the ordinary Bordeaux or the modified Bordeaux mixtures the injury was so slight on this variety as to be insignificant and was far overbalanced by the benefits. However, the foliage of the York Imperial suffered seriously, too much to be tolerated if it could possibly be avoided. As the York Imperial is the most immune to copper poisoning of all important commercial varieties as far as fruit is concerned, the net result is that even on that variety, on account of the serious damage to foliage, Bordeaux mixture is to be discarded if other fungicides can be used to do the work without this leaf injury.

Neutral Bordeaux mixture was the worst form and did more harm than the standard 3-3-50 formula, while the 2-3-50 formula, with its excess of lime, was distinctly superior to the other kinds and gave good commercial results on the York Imperial. In blocks of the York Imperial this 2-3-50 Bordeaux mixture with 2 pounds of arse-

nate of lead might possibly still be used, although it is a little too severe on the leaves.

On the other hand, under the conditions obtaining at Winchester, Va., and the same was true at other points in Virginia during 1909, the self-boiled lime-sulphur with the arsenate of lead added gave practically perfect commercial results on the fruit and entirely satisfactory results on the foliage except where cedar rust was abnormally bad, without any russetting or leaf injury whatever. The fruit seemed to be even brighter and yellower than normal fruit. This mixture has not proved to be a very powerful fungicide for apple diseases under extreme conditions.

It should be noted that Mr. W. M. Scott, of the Bureau of Plant Industry, has developed the self-boiled lime-sulphur mainly as a fungicide for use on the peach, for which purpose it is eminently successful. The down on the peach skin serves admirably in retaining the mixture on the fruit. Mr. Scott has also obtained some very good results on the apple under favorable conditions, but has pointed out that this mixture has not given entirely satisfactory results in the treatment of apple scab under extreme conditions. In the experiments on pecan scab carried on by the writer during the last year in South Carolina, where heavy and frequent rains occurred, self-boiled lime-sulphur failed in preventing the attacks of this fungus.

The self-boiled lime-sulphur does not appear to withstand heavy washing rains. This throws some doubt on the ability of the straight self-boiled lime-sulphur to protect against the attack of fungous diseases under varied and unfavorable conditions.

It should be noted that the self-boiled lime-sulphur permitted 2 per cent of infection on the leaves of the Ben Davis, 3 per cent on the Yellow Newtown, and 4 per cent on the York Imperial in Series I. While this amount of fungous disease on the leaves is insignificant, nevertheless, it was the highest obtained in any of the plats of this series. It therefore brings out the doubt as to the fungicidal strength of this otherwise remarkably good mixture.

The new form of iron sulphid gave practically perfect results on both leaves and fruit of all varieties. It was absolutely noninjurious. Furthermore, it gave the most perfect protection from fungi, the fruit having no infection whatever and the leaves being given a mark of one-half of 1 per cent of fungous injury on all varieties. The foliage on this plat had a particularly fine dark-green color and held on later than any other leaves in the orchard. The twigs were stockier and the buds were finer and plumper than on any other plat, although the self-boiled lime-sulphur plat was a close second in this regard. It should be noted, however, that the fruit was slightly greener in color and apparently a little later in ripening than on the other plats,

particularly the lime-sulphur plat, its real competitor in efficiency. In the case of the Yellow Newtown, the slightly greener color might not be objectionable. With the York Imperial it was not sufficiently marked to be important. On the Ben Davis it might possibly be slightly objectionable, unless by allowing the fruit to hang later it eventually attained full color.

On plat 7 the new form of copper sulphid gave entirely satisfactory results on both fruit and foliage of the Yellow Newtown and the York Imperial varieties. It gave excellent results on the foliage of the Ben Davis, but russeted the fruit about 10 per cent—that is, one-sixth as much as standard Bordeaux mixture. Under the conditions at Winchester the new copper sulphid was almost, if not quite, absolutely harmless on the Yellow Newtown and the York Imperial, and this is the only copper spray of which this could be said. If these results can be depended upon in the future, this spray could be used commercially with excellent success. The 10 per cent of russetting of the Ben Davis would entirely prohibit its use on that variety if the self-boiled lime-sulphur and the iron sulphid prove as efficient as indicated by this experiment. The percentage of russetting on the Ben Davis might possibly be reduced by cutting down the amount of copper from 2 pounds to 1 pound, or even to one-half pound. Furthermore, this copper sulphid may prove to be noninjurious on the Ben Davis fruit after it has reached a certain stage of growth. We may say, therefore, that we have in the copper sulphid the least injurious form of copper, and if copper is absolutely necessary for ultimate success in controlling the most difficult diseases, this form of spray produces the minimum amount of injury.

One of the surprises of this experiment was the remarkably good result obtained from the arsenate of lead plat, it showing entire freedom from russet injury. Under the rather easy conditions in regard to fungous infection prevailing at Winchester during the season in question arsenate of lead proved efficacious in preventing fungous diseases. It is certain that under more adverse conditions this freedom from fungi can not be depended upon to the extent indicated in these experiments.

The efficiency of the arsenate of lead cast some doubt as to whether it was not concerned in the success of the self-boiled lime-sulphur and the iron-sulphid plats, and perhaps some of the others, since it was added to all of the mixtures used. Self-boiled lime-sulphur, however, has been successful in several of Mr. Scott's experiments on the apple, and still more so on the peach, and it is now recognized as the standard fungicide for the summer treatment of peach diseases. An iron sulphid somewhat similar to this one, made with the sulphur solution, in the experiments of Mr. W. H. Volek, at Watsonville, Cal., on the powdery mildew of the apple, proved superior to Bor-

deaux mixture. Possibly this form of iron sulphid may possess superiority in the case of certain other fungi.

It is, however, not considered safe to recommend either the iron-sulphid or the copper-sulphid spray for general commercial use until they have been further tested. It is quite possible that different dilutions may be found desirable. Perhaps the self-boiled lime-sulphur may be reenforced in its fungicidal properties by adding just a little bluestone, say 1 pound or even half a pound per barrel. It would thus be a very dilute copper sulphid with an excess of self-boiled lime-sulphur. It is possible that the amount of copper sulphate added might be adjusted to suit the susceptibility of the different varieties. The full amount—2 pounds—could be added for the Yellow Newtown, York Imperial, and probably some other varieties, while the minimum amount of 1 pound or perhaps even half a pound could be added for the Ben Davis.

The iron sulphid made with the self-boiled lime-sulphur as a basis sticks so much better than self-boiled lime-sulphur and in the test above described was so successful that it seems very promising. It is capable of endless modification. Perhaps a smaller quantity than the 3 pounds used in the experiment could be added to the barrel of 10-10-50 or 8-8-50 self-boiled lime-sulphur with beneficial results. This may serve as a sticker for the self-boiled lime-sulphur mixture and increase its fungicidal powers. It may permit the use of an even more dilute form of the self-boiled lime-sulphur than the 8-8-50 formula which is now recommended for commercial preparations.

There is a possibility of combining the two mixtures of iron sulphid and copper sulphid in various preparations for those fungous diseases or combinations of fungous diseases that occur. For instance, if the cedar rust requires copper for its control it may be preferred to add a little copper to the iron-sulphid mixture. It is evident that considerable experimenting will be needed to settle these questions.

The harmless character of the iron sulphid is believed to be pretty well shown. It will require tests under severe outbreaks of fungous diseases before its fungicidal powers can be properly determined, however. The iron sulphid or even the copper sulphid will not be recommended for commercial work until further tested. They should be tried, if at all, in experiments in a small way. Mr. Scott has shown that the commercial lime-sulphur solution diluted to $1\frac{1}{2}$ gallons per 50 gallons of water is a more powerful fungicide than the self-boiled lime-sulphur preparation and is perfectly safe at that strength on the apple. This mixture is therefore recommended in spraying the apple and is available for those cases where apple scab or some other serious disease is feared and a stronger fungicide than self-boiled lime sulphur is desired.

Where a dangerous outbreak of bitter-rot occurs late in the season, probably, with our present knowledge of the subject, a moderately strong Bordeaux mixture—say 4-4-50—would still be the safest thing to recommend for use.

CONCLUSIONS.

All the fungicides containing copper used in the tests here reported upon russeted the fruit of the Ben Davis apple seriously, injuring it from 10 to 60 per cent.

The copper-sulphid preparation made from self-boiled lime-sulphur was the least injurious copper spray, causing only 10 per cent of injury to the fruit of the Ben Davis trees.

Neutral Bordeaux mixture proved the worst spray mixture used, even injuring the fruit of the York Imperial. An excess of lime, therefore, is an advantage in tending to render Bordeaux mixture harmless.

Standard Bordeaux mixture, 3-3-50, was the next to the worst mixture for spray injury, giving 60 per cent of injury on the Ben Davis fruits. Cutting down the quantity of copper sulphate in Bordeaux mixture from 3 to 2 pounds reduced the injury, but did not prevent it.

Copper poisoning occurs seriously on the leaves, even damaging them to a greater extent than the fruit, reaching 80 per cent on the Yellow Newtown when Bordeaux mixture is used.

The susceptibility of the leaves to copper poisoning bears no direct relation to the behavior of the fruit in this regard. The leaves of any variety may be badly injured while the fruit is not hurt, or vice versa.

Adding certain materials, such as gypsum, iron sulphate, lime-sulphur solution, etc., to Bordeaux mixture in all cases reduced the injury, but did not entirely prevent it except in the case of the self-boiled lime-sulphur in part, where a new compound was formed.

A new form of copper sulphid was made, the self-boiled lime-sulphur being used as a basis, and tested for the first time, proving effective and almost completely noninjurious except to the fruit of the Ben Davis variety.

A similar fungicide made with the commercial lime-sulphur solution was only slightly more injurious to the fruit, but was distinctly injurious to the foliage.

A new iron-sulphid fungicide was made and tested for the first time. It was entirely harmless and gave remarkably good results under the conditions at Winchester, Va., in 1909, except that it produced distinctly greener fruits. It may therefore be regarded as promising.

Arsenate of lead, 2 pounds to the barrel, can be used in any of the mixtures tested. When used alone this insecticide seemed to possess considerable fungicidal value, though probably not enough to be depended upon for general use.

Approved:

JAMES WILSON,

Secretary of Agriculture.

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